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# BMDO Update

Linking American Businesses to Ballistic Missile Defense Technology

[www.bmdotechnology.net](http://www.bmdotechnology.net)

## Watching the Earth —by Jennifer Huergo

*Remote sensing technologies offer unique views of our world.*

Remote sensing of the Earth's surface has been going on in some form or another since hot air balloons were first sent aloft. Since that time, we have steadily increased the number of reasons we have gone aloft, the ways in which we have sensed the Earth, and the heights to which we've gone. In the last decade, the number of sensor platforms in space has exploded. Both commercial and military satellites are constantly watching the Earth and its inhabitants in many different bandwidths and with many different goals. Analysts have predicted that by 2005, a commercial imaging market could generate at least \$2 billion in annual revenues.

Military applications have long dominated the skies above, collecting data on enemies, troop movements, and weapons buildups. The missions of these military satellites moved beyond observation with the development of a space-based defense system, which today is the responsibility of the Ballistic Missile Defense Organization (BMDO). Finding ballistic missiles against the complex and dynamic background of the Earth's surface from space has required significant advancements in sensors, data processing, and even our understanding of the atmosphere.

This research has also led to a growing commercial market for remote sensing data. Today, municipalities, private companies, and the U.S. government rely on a handful of commercial satellites for remote sensing information. Images of the Earth in a variety of wavelengths can be used in city planning, disaster remediation, weather forecasting, mapping, and many other applications. Sensors that can help us distinguish between types of vegetation or minerals can serve in oil or other resource exploration; they also can be used in precision farming to observe the soil and irrigation conditions of even the smallest plots of farmland. A library of images that offer before-and-after views of a site affected by natural disaster or war can help make real the scope of a disaster and perhaps help us avoid future disasters.

Several BMDO-funded companies are participating in the growth of the remote sensing industry through development of new sensors and ways of processing the data they provide. Physics Innovations, Inc. (Inver Grove Heights, MN), is building an

imager that can sense circularly polarized light, which will expand our range of vision and give us new information with which to interpret our world. SAGE Technologies, Inc. (Manhattan Beach, CA), is developing algorithms that will help make the most of today's advanced sensors by overcoming their inherent noise limitations. Kestrel Corporation (Albuquerque, NM) is leading the way

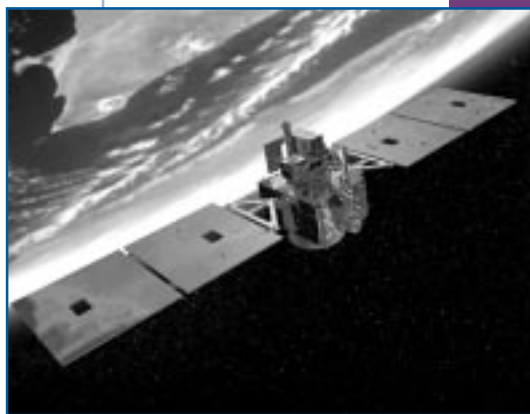


Image courtesy of Spectrum Astro

**Long look.** For over 16 months, a hyperspectral imager developed by Kestrel Corporation observed the Earth from the Air Force's MightySat II.1. The device was developed with funding from BMDO and the Air Force Research Laboratory.

in one of the most eagerly anticipated remote sensing technologies, hyperspectral imaging. A hyperspectral imager from Kestrel, one of the first in space, observed the Earth from the Air Force's MightySat II.1 for over 16 months.

*Continued on page 12*

# BMDO Update

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## We're listening...

... to what you, the readers, told us. Let me explain. In the Winter 2000/2001 issue, we included a readership survey form. Conducting a survey helps us get a better understanding of who you are, what you want to read, and how you want to read it.

After tallying the responses, we found that some like the newsletter just as it is. That's great! We also found that many aren't using the reader request card like they used to. In fact, practically everyone is either calling or e-mailing companies directly. Hmmm.

Based on your responses, we've decided to remove the request card from the newsletter. In addition, we moved company contact information from page 11 of the newsletter to the end of each article.

We're also working on other changes, too. For example, you will soon be able to view and search recent issues of the *BMDO Update* online at [www.bmdotechnology.net](http://www.bmdotechnology.net).

As with all things, change happens. I hope you like the changes we've made so far, and I'm betting you'll also like the changes we've got planned. Why am I so sure? Because we're listening to your responses. Please feel free to contact me to discuss any change we make.

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## Letters

Why doesn't the *BMDO Update* list references, such as peer-reviewed papers, at the end of each article?

Nicholas Diakides  
Advanced Concepts Analysis

*Editor's note: Simply put, it's due to limited space. The BMDO Update's mission has long been to expose our readers to many BMDO-funded technologies with strong commercial promise. If we included references for each article, we would have to reduce the number of technologies featured in each issue. That won't cut it with our readers. However, we understand that this type of information is quite valuable to some as they evaluate technology. That's why we provide a Web site address for each technology developer. Often, these sites will offer additional technology information, such as white papers, fact sheets, peer-reviewed papers, etc.*

## Success

In the Fall 2001 issue, the *BMDO Update* featured an article about a low-temperature joining process developed by Materials Resources International (Landale, PA) with BMDO SBIR funding. Ronald Smith, the company's president, says the article generated two purchase orders, one request for quotation, and two calls from editors wanting to publish full-length articles. "We were very pleased to get calls as soon as the article hit the street," added Smith. Now that's great news!

#### BMDO REFINES ORGANIZATIONAL STRUCTURE

On October 1, 2001, BMDO reorganized to address new missile defense objectives and direct the organization's focus on segments of the missile course from launch to targeted location. These changes were based on guidance received from the Secretary of Defense and Congress. BMDO remains committed to the 1994 Department of Defense directives that assigned the missions, functions, and responsibilities for ballistic missile defense programs, projects, and activities to BMDO. The primary changes BMDO implemented include:

- Restructuring the organization to reflect an integrated missile defense program, which is grouped by the missile threat segments of boost, mid-course, and terminal stages of attack. Research and development activities in support of these segments would use, as appropriate, sea, land, air, and space platforms and systems.
- Assuming responsibility for the Airborne Laser, Space-Based Laser, and Space-Based Infrared System Low that were formerly managed by the Air Force. This change will enable BMDO to explore and

develop technologies that span multiple platforms and environments.

- Transferring PAC-3, MEADS, and Navy Area to the other armed services for acquisition management.

These changes will help facilitate development of an integrated, layered defense using multiplatforms with multitiers of systems to engage and defeat all ranges of the missile threat in all phases of the threat profile.



Image courtesy of Team ABL

**Diverted.** The U.S. Air Force is transferring responsibility for the Airborne Laser (ABL) flying platform to BMDO. The ABL is designed to attack theater ballistic missiles in their boost phase of flight, when they are most vulnerable and predictable.

#### COMMERCIALIZATION IS A CONTINUOUS PROCESS

During the past decade, the *BMDO Update* has featured hundreds of innovative BMDO-funded technologies with strong commercial promise. In many cases, the companies featured were still in the early phases of technology commercialization. Even after appearing in the newsletter, the BMDO Technology Applications program continues to track these companies as they grow their businesses, further refine their technologies, and draw nearer to the marketplace. Here are a few examples:

- **Gemfire gets big backers.** Gemfire Corporation (Spring 1999; "Beatin' Those Low-Power Blue Laser Blues") recently raised more than \$63 million in its Series C round of funding from a variety of blue chip and venture investors, including Cisco Systems, Corning, Finisar, Intel Capital, and

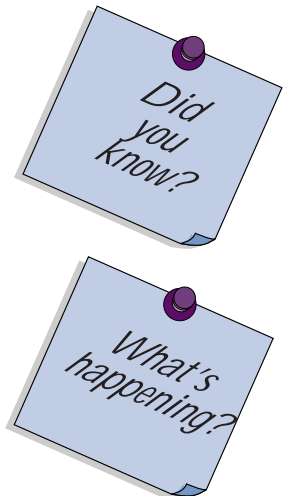
TriQuint Semiconductor. This brings the total investment in the new company to date to more than \$85 million. Gemfire's new products integrate passive and active functions on one optical chip. More information is available at [www.gemfire.com](http://www.gemfire.com).

- **Maxdem spins off new company.** Maxdem, Inc. (Winter 1995; "Plastic With the Strength of Steel"), spun off a new company, Mississippi Polymer Technologies, Inc., to commercialize Parmax® Self-Reinforced Polymers, a family of high-performance thermoplastic materials. More information is available at [www.mptpolymers.com](http://www.mptpolymers.com).

- **NVE, Agilent Technologies team up.** NVE Corporation (Summer 2000; "Magnetic Biosensor Evolves from Materials Research") signed an agree-

ment with Agilent Technologies. Under the agreement, Agilent gains non-exclusive rights to certain NVE technology, which Agilent will incorporate into future products. NVE will receive over \$1 million in fees and advance payments in the first year of the agreement, as well as future payments based on sales of the Agilent products covered by the agreement. More information is available at [www.nve.com](http://www.nve.com).

- **TDI produces first true GaN bulk substrate.** Technologies and Devices International, Inc. (TDI; "Future So Blue"), recently announced the production of the first true gallium nitride (GaN) bulk substrate. Typical applications for pure GaN substrates include blue-spectrum high-brightness light-emitting diodes and semiconductor "blue" laser diodes.



# SOLAR CELLS FROM A BEAKER

Cheap, flexible solar cells attached to windows, roofs, and roads: While it may

metallofullerenes and carbon nanotubes; the inclusion of the carbon nanotubes

increased the photocurrent by a factor of three. With further control of the electron acceptor material through the ISAM process, Luna believes it can significantly increase the photovoltaic response.

In addition to photovoltaics, the company's process is being used to develop nanostructured displays, electrochromic

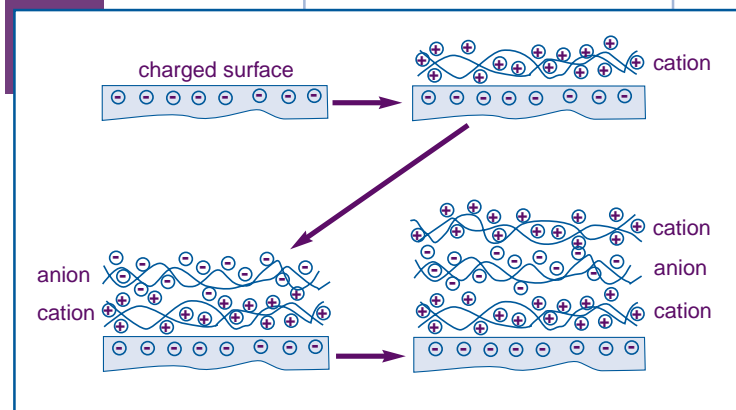
switches, and electronic devices. For example, a prototype electrochromic switch achieved a response time of less than 50 microseconds—the fastest yet observed from an electrochromic polymer, according to Luna. Other thin-film products being developed using the ISAM process

include corrosion-inhibiting films, carbon nanotube-based processors, and light-emitting diodes. Luna is actively seeking potential partners interested in device development and commercialization, particularly for the consumer electronics and solar cell markets.

—P. Hartary

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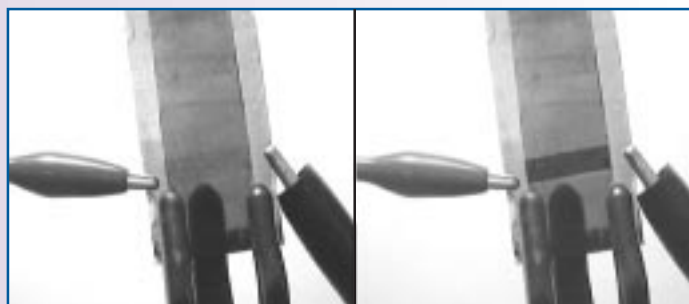
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**Layer by layer.** Luna's process simply involves the dipping of a charged substrate alternately into polycationic and polyanionic aqueous solutions at room temperature. Multilayer films, several microns in thickness, are easily fabricated by repeating the dipping process with no limit to the number of layers that can be deposited.

sound like a dream, research at Luna Innovations, Inc. (Blacksburg, VA), may soon make this vision a reality. The key to this dream is Luna's ionically self-assembled monolayer (ISAM) process, which, with the help of an applied voltage, can form thin films of conducting organic polymers from chemical solution. And, because the ISAM process does not require the expensive vacuum-based equipment used to make silicon and other semiconductor-based solar cells, production costs should be dramatically lower.

While the solar cells produced at Luna are not yet as efficient as today's silicon devices, the cost savings should be enough to allow widespread use, particularly in applications where cost is a factor but size is not (such as the rooftop application mentioned above). In addition, Luna is working to increase energy conversion efficiencies. A recent prototype included for the first time endohedral



**Voltage on, off.** The images above show a prototype ISAM electrochromic device in its "off" state (left) and in its "on" state (right). More recent prototypes have achieved switching speeds of 25 to 50 milliseconds, which are nearly fast enough for display applications.

## CONNECTING WAVEGUIDES AND OPTICAL FIBERS

Optical fibers and waveguides often join in less-than-ideal unions. When relatively large single-mode fibers encounter small single-mode waveguides, the geometric mismatch results in light loss. But a new three-dimensional (3-D) lithographic process from RVM Scientific, Inc.

**RVM's lithography process ensures a smooth transition between optical fibers and devices.**

(Santa Barbara, CA), is making possible better couplings to reduce the chances of loss. The key to this process is the penetration of light to different depths depending on its wavelength. As a result, properly selected light sources can control in 3-D the photochemical reactions that change the refractive indices of the material, thus defining the optical dimensions of the finished device. The results are tapers and buried waveguides that provide a smooth transition from fibers to devices and back again by changing size, shape, or depth within a single substrate.

Compared with competing reactive ion etching or mechanical processes, RVM's technology provides lower-cost and less-complicated fabrication of tapers and waveguides. Devices built with this process can have varying refractive-index gradients with lower light loss and lower drive voltages than those built

with other methods. In waveguides, RVM's optical process produces large single-mode index boundaries that are similar to those found in optical fiber, reducing light loss. Additionally, the process can make waveguides equal in size to an optical fiber, about 6 to 8 microns, eliminating the mismatch that also causes loss. Deeper into the polymer device, the waveguide tapers down to 1.5 to 2 microns with precisely defined boundaries, allowing close positioning of drive electrodes for low voltages.

BMDO supported RVM's research through an SBIR Phase II for advanced processing of nonlinear optical materials, with the goal of over-

coming the light loss that results from size mismatch between fibers and waveguides. RVM would like to hear from companies interested in licensing or purchasing its patented multicolor lithography technology.

—J. Huergo

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Image courtesy of Corning

**Better couplings.** RVM Scientific's process offers the potential to reduce optical insertion losses through high-efficiency electro-optical matching of waveguides and fibers.

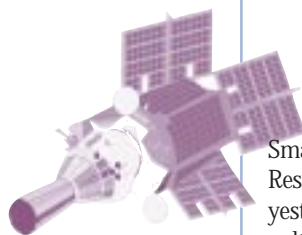
## VIDEO/CD EXPLAINS ALL TO BMDO-FUNDED ENTREPRENEURS

Attention BMDO-funded researchers: Many of you may not be aware of the commercialization services available to you free-of-charge through the BMDO Technology Applications program. All BMDO-funded researchers—even those who have not received funding from our organization for years—have free access to mentoring, business development, and outreach services to commercialize the technology and products that have resulted from BMDO-funded research. Whether you are an early stage developer or already have a prototype, these services can help you develop strategic partnerships, define a business strategy, obtain needed guidance from experts with records of success, and attract capital to scale up your technology for commercial and defense use.

BMDO just released a new video/CD that explains its commercialization review and outreach services. Take a look. Your ultimate success in scaling up your technology is likewise BMDO's success for your technology's use in future acquisition programs.

*For a free copy, call (703) 518-8800, extension 500. Leave your name, mailing address, and telephone number. Please indicate whether you would like to receive the video OR the CD.*





# BMDO TECHNOLOGY SPIN-IN: FROM SBIR TO SBIRS LOW

*EMCORE PV is but one of many examples of how BMDO SBIR technology is likely to address—or already is addressing—missile defense requirements. Other examples of such SBIR companies can be found at <http://www.acq.osd.mil/bmdo/bmdolink/html/spinin.htm>.*

Some of BMDO's high-risk Small Business Innovation Research (SBIR) R&D from yesteryear may supply photovoltaic power for BMDO's satellite systems of tomorrow. More than a decade ago, EMCORE Corporation (Somerset, NJ) developed a TurboDisc™ metal-organic chemical vapor deposition (MOCVD) process under the BMDO SBIR program. Its subsidiary, EMCORE Photovoltaics (PV), is now using the process to fabricate advanced photovoltaic cells for the next-generation solar power system of the Space-Based Infrared System (SBIRS) Low. SBIRS Low, funded by the U.S. Air Force and BMDO, is part of an integrated tactical warning/attack assessment system that combines National and Defense infrared detection systems into a single architecture. It will play an important role in protecting the nation as well as our friends and allies against missile attacks.

Compound semiconductor solar cells are ideal for applications such as SBIRS Low because they can better tolerate radiation levels in space and have higher power-to-weight ratios than their silicon-based counterparts. These features ultimately increase a satellite's life span and payload capacity. For SBIRS Low, EMCORE estimates its technology can provide these weight and radiation-tolerant benefits at a significantly lower cost than existing technology.

## In the Beginning

BMDO SBIR funded the then-57-employee EMCORE in 1988 and 1989 to develop a

process for making compound semiconductors using atomic layer epitaxy in a rotating-disk reactor. MOCVD was a principal deposition technology process during the formative period of compound semiconductor materials, but arguably, it was viable only on a laboratory scale. EMCORE's TurboDisc opened the door to controlled, high-quality material growth to support full-scale commercial production. Using TurboDisc, EMCORE has produced many wide-bandgap semiconductor materials, including gallium nitride.

## Ensuring Technology Readiness and Helping the Economy

Now an SBIR graduate with 625 employees, EMCORE (NASDAQ: EMKR) has commercialized TurboDisc reactors and sells them for a broad range of electronics applications such as lighting, wireless communications, photovoltaics, and memory storage. It also produces and sells its own line of compound semiconductors. In 2000, the company experienced \$152 million in sales and established many joint ventures and partnerships including those with Agilent, General Electric and General Motors.

As part of these commercialization efforts, EMCORE three years ago opened the doors to EMCORE PV, which relies heavily on TurboDisc reactors to produce high-quality solar cells. EMCORE PV is working closely with several large telecommunications concerns to help them develop solar cell and other process technology for commercial satellites. As a result of this col-

laboration, EMCORE PV has produced gallium arsenide solar cells that are 50 percent more efficient in light-to-power conversion than silicon-based solar cells, and are also more radiation resistant. The resulting advancement allows satellite manufacturers to increase the useful life span and payload capacity of satellites. In the past two years, the company's customers have purchased several MOCVD production systems for this purpose.

EMCORE PV also won a \$4.5 million contract from the DOD Dual Use Science and Technology (DUST) program to demonstrate a new material, InGaAsN, as a viable photovoltaic material and to integrate it into a 4-junction solar cell to increase solar cell efficiency more than 35 percent. This project, funded by the Air Force and the National Reconnaissance Office, is being targeted for the next-generation SBIRS Low. Important to the DUST project, EMCORE also signed an agreement with Loral to supply compound semiconductor high-efficiency gallium arsenide solar cells for satellites. This partnership should ensure the insertion of the technology into future space satellite systems for the military.

—L. Aitcheson

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### STREAMLINING WAVEGUIDE PRODUCTION

Waveguide writing may soon get a lot easier and cheaper, thanks to a clever use of an ultrafast femtolaser developed in part through BMDO SBIR research. With the short wavelengths that this laser produces, Translume, Inc. (Dexter, MI), can directly write waveguides into glass, speeding the production of beamsplitters, couplers, and other optical components that need waveguides. In contrast, most waveguide production today is done using planar technology, a complex process of growing waveguides on silicon substrates layer-by-layer. Translume's laser can write in 2-D or even 3-D patterns, allowing for more complex circuitry than can be achieved in the same space with planar technologies, which are limited by the physical properties of the substrates. Also, a waveguide writing approach using Translume's

femtosecond laser would cost only about \$2 to \$3 million to implement, much less than the \$40 to \$50 million needed for a planar-based facility, while providing similar manufacturing throughput.

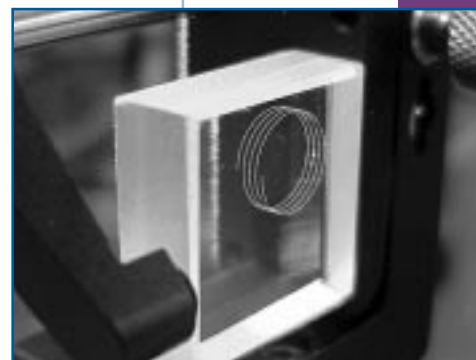
The femtosecond laser was originally developed by Clark-MXR, Inc. (Dexter, MI), with the help of BMDO SBIR contracts as well as funding from Michigan's Department of Commerce and State Research Fund. Clark-MXR now provides customized micromachining services based on the laser, sells the laser as a stand-alone device called the CPA-2001, and also sells a femtosecond laser-based micromachining workstation. In 2001, Clark spun off Translume, Inc., to manufacture waveguides using its femtosecond lasers. Translume received an initial round of venture capital funding from Ardesta LLC, and is

planning to deliver prototypes by the end of 2001 with commercial production to start shortly thereafter. The company welcomes inquiries from potential investors and from companies interested in using its custom waveguide manufacturing capability.

—J. Jackson

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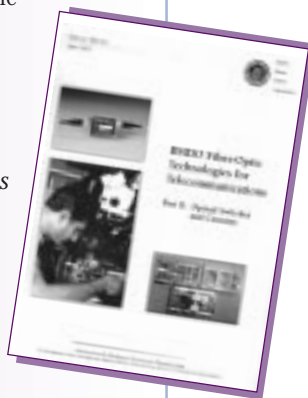


**3-D pattern.** Traditional waveguide devices are two-dimensional. However, Translume can manufacture 3-D devices, allowing for more compact designs. This image shows a 3-D pattern (helix) written in a chunk of glass using the company's direct write femtosecond laser process.

#### TECH TRANSFER PUBS: HARD COPIES STILL AVAILABLE

Create a BMDO technology library with publications from the BMDO Technology Applications program. While many can be viewed online at [www.acq.osd.mil/bmdo/bmdolink/html/pubs.htm](http://www.acq.osd.mil/bmdo/bmdolink/html/pubs.htm), some are still available in hard copy, as listed below. To order any publication free-of-charge, call (703) 518-8800, extension 500. Leave your name, mailing address, telephone number, and the name of the publication.

- 2000 BMDO Technology Applications Report
- 1998 BMDO Technology Applications Report
- 1997 BMDO Technology Applications Report
- BMDO Fiber-Optic Technologies for Telecommunications
  - Part I: Optical Amplifiers and WDM Technologies
  - Part II: Optical Switches and Circuitry
- BMDO Technologies—Improving the Environment
- BMDO Technologies for Biomedical Applications



"Not everything that can be counted counts, and not everything that counts can be counted."

—Albert Einstein

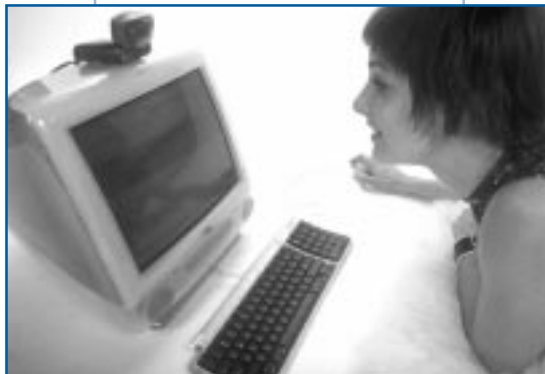
### FINDING THE KNOWLEDGE YOU NEED

To a computer, telling the difference between a missile and a decoy is not that different from telling the difference between a useful and a useless document on the Internet.

Using this idea, Torch Concepts, Inc. (Dulles, VA), has taken the Maximum Likelihood Adaptive Neural System (MLANS) algorithm, which was originally developed for BMDO missile discrimination, and extended it to the analysis of symbolic (e.g., textual) information. This extended technology, known as ACUMEN, is currently being used to develop content management software. More than just a search engine, this software automatically analyzes documents returned by a search and sorts them into categories, labels the categories, and summarizes each document.

Say, for example, you type in the word "mercury" using a standard search engine. The document list returned doesn't discriminate between references to the planet Mercury, the Mercury space mission, or the Mercury line of cars. Torch Concepts' software will perform an extensive search of the Internet and available intranets, then sort and prioritize the search results, returning first a list of categories: solar system, space missions, and cars. If the user selects a category, the software pro-

duces a summary of each document within the category. If the user selects multiple categories, it subcategorizes the documents and produces a summary for each document within the subcategory. With



**More relevant content.** *Because of the accuracy in categorization and summarization offered by Torch Concepts' software, employees spend less time looking for information they need, leading to a more productive workforce.*

this software, users can find what they're looking for without opening irrelevant documents.

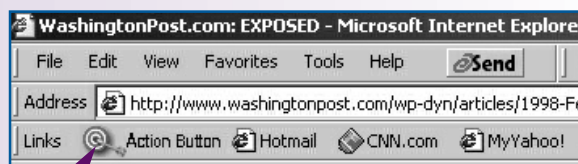
Two private companies have already licensed the software. Reveal Technologies is developing a product, called My Virtual TextBook, that helps educators programmatically recognize and organize the topics and content of online documents. Educators

will appreciate this product because it will save them time by automatically designing educational plans using the most up-to-date and relevant information found on the Internet. True Aim Technologies is developing ActionButton for browsers. This button allows one-click access to additional relevant documents from anywhere online, saving time spent digging through internal databases and external Web sites. Torch Concepts is actively seeking additional licensees for its software.

—P. Hartary

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**One-click access.** *When the user clicks on ActionButton, the software scans the content being read, determines the topic, and then displays related content from preselected sources, including internal databases and external Web sites.*

### TAMING BALL LIGHTNING

For over ten years, Clint Seward of Electron Power Systems, Inc. (Acton, MA), has been on a mission. He's been trying to show that ball lightning—a rare and unexplained natural event in which a spherical cloud glows for as long as a minute—could hold the key to a revolutionary energy technology. This mission recently passed an important milestone as Dr. Chipping Chen, a research scientist at the MIT Plasma Science and Fusion Center, has confirmed the existence of a generic class of self-organized plasma toroids, stable in atmosphere with no external magnetic fields required for containment. A paper by Chen, Pakter, and Seward will be published in October in *Physics of Plasmas*.

#### Credible science

Chen's work supports Seward's experimental research on plasma toroids, which began after theorizing that ball lightning is a naturally occurring self-organized plasma toroid. Since producing small, short-lived, self-organized plasma toroids in the lab—which he calls spiral plasma toroids (SPTs)—Seward has concentrated on developing a theoretical framework to explain their existence. This framework was essential, he thought, to obtain the scientific credibility he needed to sustain a long-term program for building larger, more practical SPTs. Seward and Chen presented a paper at ICOPS 2001 titled "Ball Lightning Explained as a Stable Plasma Toroid."

With Chen's theoretical work published, Seward now has this stamp of approval on the physics, and he can start moving toward his ultimate goal and that of the BMDO STTR program managers who funded some of this work: a workable energy storage device for propulsion or directed energy weapons.

For instance, Chen has suggested a radical new propulsion system based on this technology. Theoretical calculations suggest that the SPT can be accelerated as an entity at up to 600,000 m/s. This would provide thrust in atmosphere with a specific impulse of 60,000 seconds, compared to the 500 seconds for chemical systems. This improvement in specific

**Ball lightning could hold the key to a revolutionary energy technology.**

impulse means that rockets using the SPT unit would be able to carry 120 times less propellant. While similar accelerators are being developed using compact toroids at Kirtland AFB, SPTs can be made rapidly in a simple apparatus, and can last in atmosphere.

By directing the SPT beams outward from a gun, instead of backward from a rocket, the SPT could also be used to form a new kind of directed particle beam that would travel through atmosphere. Such a system would project significant force and energy through atmosphere

and onto an incoming missile or aircraft. And, at 600,000 m/s, it would be projected rapidly over long distances.

Finally, Seward has also calculated that the technology will increase the capacity of charged particle traps by an order of magnitude. If so, it can be useful for storing protons, ions, and antimatter. This will have long-term benefits in the field of energy storage and power generation.

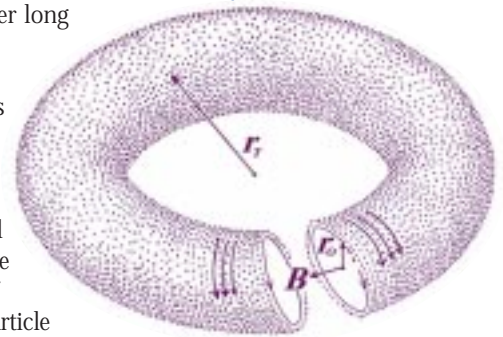
#### Next Steps

Seward says the next steps for developing the technology are clear. Plans are on the drawing board to make a larger, more practical SPT. "The physics provide guidance on how to modify the present experimental apparatus to do this," added Seward. "There is no technical impediment, just time and effort." The scale-up will allow the demonstration of the particle trap technology, and will lead to experiments to demonstrate the SPT acceleration. Seward is looking for strategic partners to complete these experiments.

—T. Lynch

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**Plasma ring.** A conceptual drawing of Electron Power System's spiral plasma toroid (SPT). Electrons travel in parallel orbits around a torus, which produces an internal magnetic field. According to recent theoretical work by Chen, at sufficiently high electron densities, SPTs will be stable in atmosphere with no external magnetic fields.

## STACKABLE PIEZOELECTRIC ACTUATORS FOR VIBRATION GENERATION OR SUPPRESSION

If one piezoelectric unimorph actuator is good, stacking two must be twice as good.

Unfortunately, getting stacked unimorph actuators to work in harmony to combine their forces often results in inefficient devices. That is until Dynamic Structures and Materials, LLC (DSM; Franklin, TN), developed a new way to stack

piezoelectric actuators to generate more powerful and efficient actuation. BMDO SBIR funding has supported development of these stackable actuators, which can be custom-configured to suit applications in the suppression or generation of vibration. One proposed application is in the seeker assembly for BMDO's kinetic kill vehicle.

DSM's piezoelectric unimorph actuators vibrate in one direction to cause actuation in another. As a voltage is applied to the 2-inch-diameter discs, the edges move in so that the discs cup or dome, and actuation is provided in a perpendicular direction. Proprietary boundary conditions make possible the stacking of the discs to maintain power to mass levels that are greater than competing technologies.

In the form of a shaker (or vibration source), DSM's technology has been shaking things up onboard the International Space Station (ISS) since April 2001. As part of a scientific test

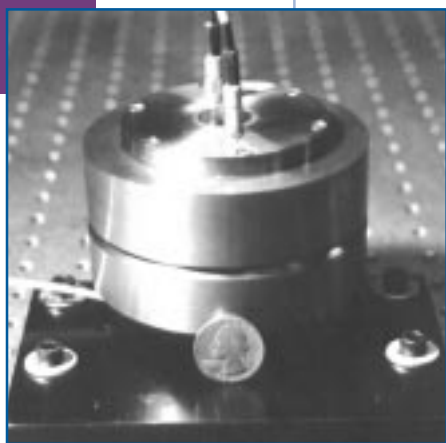
rack loaded with instruments, the DSM shaker provides an important controlled vibration source to test other vibration isolation mounts and the effects of vibration on instruments. The predictable vibration from the DSM shaker allows testing of the limits of the current active and passive vibration suppression systems on the ISS. The device operates up to 500 Hz with just 35 watts of power, and is less prone to thermal loss and mechanical breakdown than electromagnetic devices. The DSM shaker also features a single resonance peak; its axisymmetric design enables a flat and predictable dynamic response with extremely low, yet programmable, damping. In contrast, electromagnetic devices have multiple resonance peaks that limit their usefulness within specific fre-

quency ranges. With very little parasitic mass, only 5 percent of the shaker's mass is not directly involved in causing actuation. Using its actuator technology, DSM can build customized devices for generating or suppressing vibrations as well as for positioning machine tools and suppressing chatter.

—J. Huergo

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### Shaking things up.

DSM's shaker is being flown onboard the International Space Station. The technology within the device was developed through a BMDO-funded SBIR program for piezoelectric vibration suppression actuators.



**Boxed.** DSM's shaker technology, shown at right, is located inside the square aluminum housing to protect it from dislodged equipment floating inside the ISS.



Images courtesy of Boeing

**In control.** DSM's controller technology, shown on the left, controls the shaker device on the ISS.

## NEUTRON IMAGER FOR FASTER, BETTER IMAGES

Take your pick: high speed or high resolution? With today's neutron detectors, you can't have it both ways. The best neutron images come from film-based detectors, but film development is time-consuming. Electronic imagers are faster, but their resolution is worse. With the help of BMDO SBIR funding, NOVA Scientific, Inc. (Sturbridge, MA), has developed a neutron imager that can both quickly and clearly detect light elements such as hydrogen, carbon, and nitrogen. The device's speed would be useful for nondestructive evaluation of dynamic processes, such as hydrogen movement within a fuel cell. And the detector's high resolution could help reduce the size of a neutron scattering instrument, now about 30 meters in length, to about 3 meters—without increasing the cost.

NOVA's detector relies on a microchannel plate (MCP) made from boron-10 ( $^{10}\text{B}$ )-doped glass, which captures neutrons more readily than ordinary glass. This capture leads to an immediate release of an alpha particle and a lithium-7 ( $^7\text{Li}$ ) particle. The particles pass out of the glass and into one of the MCP's numerous 5-micron-diameter channels, knocking electrons free as they go. Those electrons travel toward the back of the MCP (attracted by its positive bias), bouncing against the channel walls and releasing electrons with each bounce. From a single neutron then, thousands of electrons emerge from the MCP to be electronically captured or allowed to strike a phosphor screen for imaging.

NOVA researchers have demonstrated resolutions of 25 micrometers and believe

they can achieve between 50- and 60-percent neutron conversion, compared with the



Image courtesy of Burle Electro-Optics

nearest competitor's 15-percent conversion rate. Coupled with a charge injection device, the detector is extremely radiation-hardened and could be used to image inertial confinement fusion cores. NOVA is preparing proposals and quotes for potential customers interested in non-destructive evaluation and protein research, and the company is open to inquiries regarding other applications. NOVA is working to increase the size of the detectors from a current diameter of one inch to larger surface areas that could be used for contraband detection at airports or other high-security locations.

—J. Huergo

**At the heart.** The key to NOVA Scientific's imager is a microchannel plate (MCP) made from boron-10 ( $^{10}\text{B}$ )-doped glass. As shown above, MCPs are available in a wide variety of sizes and shapes.

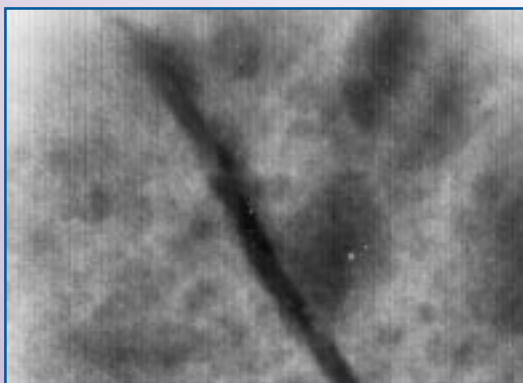


Image courtesy of NIST's Nuclear Methods Group

**Inside look.** Using NOVA Scientific's neutron imager, researchers peered inside a core sample of a concrete pillar and found moisture diffused along a microcrack.

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Watching the Earth from page 1

### Physics Innovations

When white light passes through a prism, its component colors become evident. But light has many more characteristics not immediately visible to the human eye and, until recently, not even to our instruments. When light reflects off a smooth surface, our eyes can sense its horizontally and vertically polarized components, noting the horizontal simply as glare. But there is more information in that reflection than our eyes can sense. When the two components of polarized light are out of phase, the light

is circularly polarized. Different surfaces produce different patterns of circularly polarized light, and it is these patterns that Physics Innovations' imager will recognize and record.



Image courtesy of NASA

**Noisy clouds.** Clouds create "noise" for sensors looking down on Earth. With BMDO SBIR funding, SAGE Technologies is developing algorithms that reduce the negative impact that cloud cover can have on these devices.

The company first designed a thermal imager that could sense light intensity and linear polarization. Thermal imaging sensors are often limited by the small thermal contrast between a target and its background, but polarimetric data depends on the 3-D shape and surface properties of the target. Man-made objects have unnaturally smooth surfaces, leading to radiation with greater polarization, whereas natural backgrounds tend to reflect radiation that is less polarized.

By adding the ability to detect circularly polarized light to this imager, Physics Innovations' device can better distinguish between objects with different surface properties. The key component for doing so is an achromic waveplate developed with BMDO SBIR funding

### REMOTE SENSING: WHAT IS IT?

The term remote sensing has been used to describe any sensing of an object, area, or phenomenon done without physical contact. For example, remote sensing can be done from an airplane, satellite, or even a person standing on the ground, as long as they are not in contact with what is being sensed. Used in the general press today, remote sensing has come to refer to sensing done from above the Earth's surface—from a satellite or other space-based platform. Military development of remote sensing has pushed our technologies ever further, and has led to advancements in our understandings of meteorology, mineralogy, ecology, and agriculture. Once the domain of our military, images with resolutions as powerful as one meter or less are now available over the Internet to the general public.

that converts circularly polarized light to linearly polarized light. Previous attempts to do this required an imager with either a rotating waveplate or rotating linear polarizer. Not only do these moving parts introduce mechanical complexity, they slow down the imaging process and make real-time imaging impossible. With such a device, the object of interest must remain stationary through a rotation of the waveplate or polarizer.

Physics Innovations' micro-scale achromatic waveplates eliminate these mechanical problems. The waveplates are created on a silicon substrate, which means that—because they can be fabricated using conventional microlithography—they are smaller and less expensive than competing cadmium sulfide or cadmium selenide achromatic waveplates.

The circular polarization sensors and camera are being developed through a strategic partnership with a major aerospace company. In addition to remote sensing capabilities in military, meteorological, and geological applications, Physics Innovations would like to see its imager developed for medical applications and is interested

in working with medical device manufacturers. The camera could provide enhanced images of subsurface tomography, providing more detail because of its higher signal to noise ratio.

### SAGE Technologies

As imagers are built with ever-increasing capabilities, our data processing technology must also be improved. At SAGE, BMDO SBIR funding supports the design of algorithms that can be used to suppress background clutter—the noise from phenomena in the Earth's atmosphere or on its surface—so that a missile can be more easily identified and tracked. One aspect of SAGE's work is to take into account the effects of the atmosphere between a sensor and its target. Knowing how that atmosphere influences images of both a missile and the background allows SAGE to now turn its capabilities around to study not only objects passing over the surface of the Earth, but that surface itself. SAGE is designing algorithms that can be tailored for different applications in studying crop health or fertilization and irrigation needs. Cloud cover is a significant

Continued on page 13

Watching the Earth from page 12

source of "noise" for sensors looking down on the Earth, so SAGE has devoted much research to reducing the negative impact partial cloud coverage can have on imaging.

Sometimes the noise comes from the sensors themselves, and the larger the sensors, the greater the noise level. There is tremendous sensing opportunity in today's imagers, which can have millions of detector elements but all sensors suffer from some level of general device noise or focal plane pattern noise, arising from the fact that all areas of a focal plane do not respond identically. It is also impossible to avoid a certain amount of jitter or pointing angle noise. Problems such as these keep a sensor from achieving its theoretical capabilities, so SAGE is developing algorithms that resolve and suppress noise sources. Working with East-West Enterprises (Huntsville, AL), another BMDO SBIR-funded company, as well as the Boeing Company and Space Computer Corporation, SAGE is developing its hyperspectral signal processing for infrared data, but it is also applicable to visible light.

### Kestrel Corporation

A standard color sensor that detects just a few spectral bands can differentiate between major features such as vegetation, dirt, or roads. However, a hyperspectral imager can distinguish a maple from an oak, wheat from alfalfa, and is sensitive enough to separate healthy from unhealthy growth. These capabilities are why hyperspectral imaging has been so eagerly anticipated by the remote sensing industry. Through a num-

ber of SBIR contracts, BMDO has supported research at Kestrel to improve capabilities in this field. To avoid the use of expensive adaptive optics, Kestrel designed a grating that corrects chromatic distortion in multispectral and hyperspectral imagers to increase spectral bandwidth and improve spatial resolution. The grating can be incorporated into new imager designs or retrofitted to existing imagers to improve their performance. It also has found uses in three-dimensional medical imaging.

Through the Air Force Research Laboratory (AFRL), BMDO funding also supported development of Kestrel's spatially modulated Fourier transform hyperspectral imager (FTHSI). FTHSI illustrates the technical advantages of Fourier systems over dispersive hyperspectral imagers in that it can record the full spectra without any time delay and can decouple the spatial and spectral signatures. The spectral and spatial resolution of the device can be varied electronically through one of four modes, and the imager can "see" the Earth in hundreds of spectral bands ranging from the visible to the far-infrared. For over 16 months, Kestrel's FTHSI observed the Earth from the MightySat II.1 satellite, an AFRL program for testing emerging technologies.

### Conclusion

The imagers that will one day look down upon the Earth and help us plan our cities, manage our resources, and defend our nation are being created today in small businesses across America. They were initiated to help BMDO

achieve its mission, but they will go beyond that goal and influence our economy, sometimes changing the way we do things. The commercial appetite for space-based remote sensing information is growing fast behind our increasing capabilities. When in 1994 President Clinton made publically available imaging data with resolutions better than one meter, people began to create new applications for this imagery. Today, there are a handful of companies that provide space-based remote sensing data over the Internet. This data can make certain tasks easier, such as community planning, but also enable others, such as more efficient and effective farming, fishing, or conservation. From planning communities or refugee camps to locating minerals or schools of fish, remotely sensed data promises to become an ever-growing part of our daily lives.

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**Why the hype?** Onboard the International Space Station, Kestrel's imager can "see" the Earth in hundreds of spectral bands ranging from the visible to the far-IR.

*BMDO-funded research is benefiting the remote sensing industry through the development of new sensors and data processing techniques.*

STRATEGIC PLANNING —by George Seiler



*This installment of the Business Focus FAQs continues with the topic of strategic planning. In the last issue of the BMDO Update, our consulting staff addressed the purpose of a corporate vision and the process for implementing that vision through business planning. This issue completes the topic by discussing the nuts and bolts of putting a 5-year plan to paper.*

**How Do I Lay Out a 5-Year Business Plan?**

Any successful 5-year plan must be linked to a continuous process of strategic planning, as discussed in the earlier FAQ. The formal plan, when put to paper, should contain at a minimum the elements shown in the box to the right.

George Steiner<sup>1</sup> suggests ways to approach each key element. In addition, Michael Porter<sup>2</sup> has written what many say is the definitive work on techniques for analyzing industries and competitors; one may want to apply the principles he outlines without going into as much analytical depth as he suggests.

For example, developing a "SWOT" analysis (Strengths, Weaknesses, Opportunities, and Threats) for your business can be most useful. It can also be done for key competitors. Defining the company's vision, major goals, and target customers and completing the marketing, competitive, SWOT, and critical success factor

analyses lead to operating strategies and implementation plans. How will you operate, and what are the most important things to be accomplished? What resources do you require? Are these practical?

The answers to each of these questions should lead to specific, near-term objectives with associated time-action steps. Each time-action step should address a key benchmark to reaching the goal and

the plan forward to meet the goals. Regular periodic review with written decision notes can be a significant factor in achieving the planned goals.

The financial projections can be a capsule summary of key projected financial data such as annual revenue and net income for the period. It may include sensitivity to important elements, such as selling price and volume, and may include alternative spending scenarios

based on marketplace acceptance. In any event, the financial projections should outline the sources and uses of funds and the expected cash flows.

Planning is an ongoing process. The plan can and should be refined over time. It does not have to be perfect in its first draft. The success of the plan depends upon its being owned by those responsible for achieving the results. The operational and financial results come from making effective decisions and accomplishing specific tasks.

**The Business Plan Outline**

1. Vision of business
2. Brief description of product(s) and service(s) and the estimated market
3. Target customers
4. Core strengths
5. Competitive environment and advantage, market positioning, and message strategy
6. Major goals
7. Critical success factors
8. Operating strategies
9. Implementation plan
10. Summary of financial projections

When using the plan to raise funds, it should also include a description of the management team and an estimate of the amount of money sought and how it will be used. In addition, the plan should include a well-written executive summary that succinctly communicates the key plan points. This will allow prospective investors to decide within a few minutes if your plan deserves further study.

should identify a single person responsible for its achievement. Each set of time-action steps should address the elements summarized in the "SMART" goal acronym (Specific, Measurable, Achievable, Relevant, and Time-delineated).

Plan monitoring and control is an important part of the implementation plan. It includes measurement of key results and decisions, and actions to take

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<sup>1</sup>Steiner, George F., *Strategic Planning*, The Free Press, NY, 1979.

<sup>2</sup>Porter, Michael E., *Competitive Strategy*, The Free Press, Macmillan, NY, 1980.

Many thanks to George Seiler of Profit Planning Associates for his assistance in preparing this article.

## The BMDO Update

### THE VALUE OF TECHNOLOGY INNOVATION

#### DOES IT COUNT? —by Leslie Aitcheson

PURCHASED COMPANY <sup>1</sup>	PURCHASER	DATE OF TRANSACTION	VALUATION OF TRANSACTION (in millions)	TERMS	FIRST FUNDED BY BMDO SBIR	TOTAL BMDO SBIR AND STTR FUNDING
AstroTerra	MRV Communications	Jul 00	\$159.30	Acquisition	1993	\$1,850,627
Autonomous Technologies	Summit Technologies	May 99	\$86.60	Merger	1988	\$1,833,722
Coleman Research Corp.	L-3 Communications	Dec 00	\$60	Acquisition	1986	\$1,061,542
Coretek	Nortel Networks	Jun 00	\$1,430	Acquisition	1994	\$5,625,850
E-Tek	JDS Uniphase	Jun 00	\$17,523	Acquisition	1987	\$575,986
GELTECH	LightPath	Aug 00	\$27.5	Acquisition <sup>2</sup>	1987	\$668,392
IntelliSense	Corning	Jun 00	\$750	Acquisition	1995	\$782,726
Micracor	Coherent Laser Group	Dec 96	\$1.30	Acquisition	1993	\$1,087,927
Nichols Research Corp.	Computer Science Corp.	Nov 99	\$369	Merger	1986	\$849,541
NZ Applied Technologies	Corning	May 00	\$75	Acquisition	1993	\$4,401,008
OCA Applied Optics	Corning	Apr 97	\$70	Acquisition	1997	\$60,009
Ortel	Lucent	Apr 00	\$2,950	Merger	1988	\$719,169
SDL	JDS Uniphase	Feb 01	\$13,500	Merger	1993	\$2,477,563
Sensors Unlimited	Finisar	Aug 00	\$330	Acquisition	1992	\$614,400
Silicon Mountain Designs	Dalsa	Sep 99	\$11.50	Acquisition	1994	\$1,617,978
Sterling Semiconductor	Uniroyal Technologies	May 00	\$40.60	Acquisition	1997	\$2,329,994
Thermacore	Modine Manufacturing	Apr 01	\$110	Acquisition	1985	\$6,487,283
Nitres	Cree	Apr 00	\$135	Acquisition	1996	\$4,201,737

<sup>1</sup>M&A data was unavailable for 9 additional purchased companies.

<sup>2</sup>LightPath also assumed GELTECH's debt of \$1.4 million.

Employment numbers and revenue are two of several metrics that SBIR bean counters look at when evaluating the overall effectiveness of the program. Their goal is to identify whether SBIR investments, through high-tech small businesses, have made a positive impact on the U.S. economy and the quality of life for Americans. To date, one metric that has not been pursued is that of mergers and acquisitions (M&As). In BMDO's SBIR portfolio, many companies have merged or been acquired for, in some cases, billions of dollars. We have identified 18 cases where BMDO SBIR-funded companies have transitioned to this new level.

Whether or not merger/acquisition activity really signifies a commercialization success

story is entirely up for debate. BMDO SBIR's contribution to the company's success in luring such investment varies on a case-by-case basis. In addition, many companies received SBIR funding from other agencies as well. However, it is interesting to note that, in many cases, BMDO SBIR's initial injection of capital occurred fairly early in these companies' histories. So if viewed strictly as a venture investment, it may be seen as having an impact. The total value of all mergers and acquisitions of the 18 tracked BMDO SBIR companies at the time of their merger or acquisition was more than \$37 billion. BMDO SBIR put a total of \$37.2 million into these companies prior to acquisition.

The ability to evaluate the value of the investment at the

time of merger or acquisition is beyond the resources of this program. However, with the assistance of Adams Capital, we were able to determine the valuation of BMDO's investment for one company (CoreTek) which illustrates the value of early stage seed funding. (Adams Capital was the first venture funding that CoreTek received.) We see that had BMDO's investment been viewed as an A-minus round of venture capital, its investment would be worth \$255,260,848.07 at the time of acquisition.

So the question is, does this count? The BMDO Technology Applications program welcomes debate on this metric. Send responses to [laitcheson@nttc.edu](mailto:laitcheson@nttc.edu).

*Adams Capital, a nationwide VC firm with over \$700 million under management, invests in early stage companies in the information technology, materials, and software areas ([www.acm.com](http://www.acm.com)). For further information, call Tony Warren at (814) 865-4593.*

# *BMDO Update*

WINTER

2001/2002

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## **Ballistic Missile Defense Organization**

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Address Correction Requested



WINTER 2001/2002  
ISSUE #40

### INSIDE

- SELF-ASSEMBLING THIN FILMS
- CONTENT CLASSIFICATION ALGORITHM
- STACKABLE PIEZOELECTRIC ACTUATORS
- REAL-TIME NEUTRON DETECTOR

... *and more!*

# *BMDO Update*

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